California Forest Experiment Station

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

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THE FIR ENGRAVER BEETLE

SEASON OF 1931

Progress Report

by

G.R. STRUBLE
Assistant Entomologist

Annex 1
596
.S35 S83
1932

Berkeley, California
March 1 1932

U. S. GOVERNMENT PRINTING OFFICE: 1932 J 76133

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ABSTRACT

Studies on the insects affecting white fir were begun in 1929 in the Stanislaus National Forest, as a result of an increase in the number of dying trees throughout the fir types of the Sierra. The fir engraver beetle, Scolytus ventralis Lec., was found to be the most important primary insect, and as a result the life history has been studied and carefully worked out during seasonal investigations in 1930 and 1931.

Experiments to determine the best methods of control for the fir engraver beetle occupied a considerable portion of the 1931 program. Methods applicable during the dry season were tried, which included (1) exposing brood logs to the sun; (2) the use of chemicals as insecticides or repellents; (3) submerging brood logs in water.

A study of seasonal losses on selected plots of the California Forest Experiment Station and Bureau of Entomology has been carried on for the purpose of determining infestational trends and to secure basic data on the progress of attacks on topkilled trees.

As a result of the 1931 studies certain significant points were found, as follows:

A. Life History

1. Temperatures under which brood development occurs within the bark vary between 55 and 99° F. Above and below these points development ceases.

2. It is believed that acceleration of development occurs at temperatures between 90 and 99° F., but further data are needed to confirm this point.

3. Optimum developmental temperatures are between 70 and 85° F.

4. Time required for completion of life cycle is dependent on period of exposure to temperatures within the optimum and acceleration range. At Strawberry the life cycle in 1931 was complete from eggs to adults in 46 days between July 2 and August 16, when maximum temperatures during most of the period were within the optimum range and minimum temperatures were within the developmental range. This is in contrast to 1930 development, when the development proceeded from eggs to mature larvae between July 1 and September 1.

5. Further studies on the conditions limiting successful establishment of broods were carried on by caging five trees, and showed that attacks could not be established when (a) needles and twigs were caged so that the beetles could feed on them: (b) when brood logs were placed inside the caged area, eliminating disturbance of beetles through handling; (c) when a caged tree was girdled; (d) when the caged area was on the upper smooth bark portion of the trunk.

6. Fir balsam was found to be extremely toxic to S.ventralis adults and may help to explain the lack of success of attacks.

B. Control Studies

1. Solar heat experiments

a. Fatal temperatures were determined in the laboratory by submerging vials containing mature larvae in water brought up through a range of temperatures. Temperatures above 120° F. were found to be fatal if extended for more than 15 minutes.

b. Solar heat tests were run by placing logs containing broods in a north-south direction in full sunlight. Records of temperature were taken by inserting mercury laboratory thermometers in the north ends of logs so that the bulb rested firmly in the bark. Readings were taken every two hours of exposure and compared with air temperatures in the shade.

The following conclusions were reached as a result of these experiments: (1) Suncuring is feasible when air temperatures are 80° F. or above; (2) Logs must be laid in a north and south direction where full sunlight can strike them for at least six hours of the day; (3) Logs must be rolled three times, exposing one-third of the surface to full sunlight for no less than four days at air temperatures of 80° F. or above; (4) Logs with bark more than 20 millimeters thick should be peeled, exposing the inner surface of the bark to the sun.

2. Chemical control experiments. Flu-si (sodium fluosilicate) dust, creosote emulsion, solite (petroleum oil), paradichlorobenzene dissolved in linseed oil, and thymol dissolved in alcohol, were used as repellents and insecticides. Of this number Flu-si and paradichlorobenzene gave most promise, but none was 100 per cent effective as a repellent or an insecticide.

3. Submerging experiments. Eight logs containing heavy S.ventralis broods were used. One log removed each week for a period of six weeks showed a continuous mortality from 14 per cent of the brood after one week of submergence, to 99 per cent mortality after six weeks. It was concluded that this method of control is feasible near lake shores or mill ponds; but owing to the length of time required to kill the broods its use is limited to situations where logs can be kept in water for long periods.

C. Insect Losses on Sample Plots

1. Surveys showed that much less damage was done to fir in 1931 than occurred in 1930, but the total 1931 loss will not be known until the 1932 surveys are made.

2. This decline occurred during the abnormal drought of 1931, and is in contrast to an increased infestation of D.b. and D.m. found in yellow pine and sugar pine on plots where these two species were abundant.

3. A decrease in the number of topkilled white fir trees was also noticeable in 1931.

THE FIR ENGRAVER BEETLE
SEASON OF 1931

Progress Report

INTRODUCTION

Studies on the fir engraver beetle have been carried on near Strawberry in the Stanislaus National Forest during the past two seasons. In 1929 an intensive investigation was made by J.M. Miller to determine the primary cause of death to white fir on an area being logged by the Pickering Lumber Company, where an excellent opportunity was afforded to examine a large number of infested white fir. Two insects were found to be of primary importance, first among which was the fir engraver beetle, Scolytus ventralis Lec., and second the Sierra fir borer, Tetropium abietis Fall. Many trees were examined, and a classification according to the amount of crown injury was set up. In each of four classes a definite type of infestation was recognized.

In 1930 fir insect studies were devoted in particular to the fir engraver beetle. Preliminary work was begun at the Stanislaus branch of the California Forest Experiment Station by the writer, assisted by P.C. Johnson, where intensive investigations were made to determine (1) the life history and habits of S.ventralis and associated enemies; (2) the type of trees attacked according to growth rate; and (3) the amount of injury to white fir by insects since 1927. In addition, stem analyses were run on a number of infested trees to get further information on the distribution of insects in different types of crown injury. These studies led to the discovery of a cambium-killing fungus associated with the attacks of the fir engraver beetle. The results of these investigations are set forth in a preliminary report entitled "The Fir Engraver Beetle and Associated Insects in White Fir, Season of 1930."

The need for further investigations of the fir engraver beetle was evident at the close of the 1930 season. Certain points on life history were necessary (1) to further study the factors limiting successful attacks; (2) to obtain more data on the period of the life cycle; (3) to determine the role of the cambium-killing fungus associated with the beetle, as well as points concerning its spread and a positive identification of the fuhgus.

Since the life cycle of the fir engraver beetle was fairly well determined, the development of methods of control was considered most essential in future investigative studies. Three methods were adopted in preliminary tests as follows: (1) experiments with solar heat; (2) experiments with chemicals to be used as insecticides and repellants; (3) submerging breed logs in water.

The 1931 experimental program was again carried on at the Stanislaus branch of the California Forest Experiment Station by the writer, assisted by Albert Wagner. Cooperation was secured with the Office of Forest Pathology for studies on the cambium-killing fungus. This phase of the problem was carried on by E. Wright, and will be reported in a separate paper.

Certain preliminary studies were made at Berkeley by the writer during the winter and early spring which were of value to further experiments carried out later in the field.

LIFE HISTORY STUDIES

Temperatures Favorable to Brood Development

1. Developmental temperature range for pupation and effect of constant temperatures on development. Jars containing 25 mature larvae each were placed in separate chambers at Berkeley having regulated constant temperatures of 40° F.; 52° F.; 60° F.; 75° F.; 86° F.; 95-99° F. and 104° F. Slight fluctuations in the 60° F. and 75° F. compartments made a variation of no more than 4 degrees. Examinations were made at intervals of one week to note changes in development, and the time required for adults to develop was recorded. Two tests were run, only one of which gave significant results; since in the other test considerable mortality occurred on account of predacious mites (Pediculoides ventricosis) and considerable fungus development.

In the table below are given the results of this test. The following points of significance are presented, which may prove to be quite important in determining the progress of brood under known temperature conditions: (1) the temperature range required for pupation is between 55 and 99° F.; (2) the optimum is apparently between 70 and 85° F.; (3) the period of development varies, but is apparently accelerated by temperatures above 86° F. to a maximum of 99° F.; (4) complete mortality occurs at 104° F. after a period of two weeks; (5) at temperatures below 55° F. development is checked. At 52 and 40° F., 20 per cent of the larvae died after 51 days.

Table 1 - Development of Broods at Constant Temperatures

	Degrees F.						
	40	52	60	75	86	95-99	104
Number of larvae	25	25	25	25	25	25	25
Days to first pupae			21	7	6	7	7
Days to first adults			42	14	13	14	All dead
Total days to last adults	No development in 51 days		58	28	28	21	
Total adults emerged	0	0	10	14	12	13	
% mortality of imm. stages	20	20	60	44	52	48	100

The conclusions given in the foregoing table can only be stated as tentative at the present time, due to insufficiency of data. They are, however, of some importance in explaining the unusually rapid development of S.v. broods in the field during 1931, to be taken up in the following pages.

2. Effect of 75° F. constant on period of life cycle. Two green fir logs were placed in a cage with emerging beetles at room temperature (60-75° F.) on March 13. Weekly observations were made to note the progress of attacks and broods. As soon as a good attack was established the logs were taken to a chamber where a constant temperature of 75° F. was maintained. The following is a summary of development:

First attack - - - - -	Mar. 14
" eggs- - - - - - -	" 24
" larvae - - - - -	" 30
Mature " - - - - - -	May 10
First adults - - - - -	June 8
Total period, eggs to adults- - - - -	76 days

The development as shown by this experiment continued at a constant rate, and the life cycle under these conditions was reduced from one year--which is the case under natural field conditions--to 2½ months.

3. Period of life cycle under natural field conditions at Strawberry during 1931. Two trap trees were felled June 17, one in the shade and the other in the sun. Both logs were attacked by June 23; the log in the shade had attacks on all surfaces, whereas the log in the sun was attacked only on the shaded surfaces on the under side. Development proceeded at the same rate in both logs.

Following is a summary of development:

Logs felled - - - -	June 17
First attacks- - - -	" 23
" eggs- - - - -	July 2
" larvae - - - -	" 9
Mat.larvae and pupae	Aug. 6
First adults- - - -	" 16
" emergence- - -	" 25
Total time, eggs to adults- - - -	46 days
Total time, attacks to emergence- - -	63 "

An analysis of temperature conditions is necessary at this point to explain such rapid development during the 1931 season as compared with the 1930 season, when development proceeded from the egg to the mature larval stage between July 1 and September 1. Preliminary data have indicated that temperatures unfavorable to rapid development are below 55° F. and that development is apparently accelerated at temperatures above 90° F. An analysis of 1930 and 1931 temperatures may help to explain the difference in development. The temperature data were furnished by the Stanislaus branch of the California Forest Experiment Station.

Chart 1 gives daily maximum and minimum temperatures during the 1930 and 1931 summer seasons in relation to brood development for these two seasons. The zones of development indicated on this chart were tentatively established as a result of the constant temperature studies already described. It is therefore recognized that these zones are subject to change on account of insufficiency of data; but whatever changes are made in the upper or lower limit of development will not affect the conclusions drawn from this graph comparing the two seasons of development. The temperatures favoring optimum development for 1931 are unquestionably the cause for the rapid completion of the life cycle. Although the charted maximum and minimum temperatures are air temperatures, it is expected that the bark temperatures influencing brood development did not reach the same extremes, due to the lag caused by slow heating and slow cooling of the logs. The differences were not enough to modify materially brood development.

Following is a table showing weekly maximum, minimum and average temperatures for the two summer seasons between June 17 and August 25:

Table 2 - Temperatures at Stanislaus Branch, C.F.E.S.
Weekly Averages

Date	Max. Temperatures		Min. Temperatures		Average Temperatures	
	1930	1931	1930	1931	1930	1931
June 23-30	75	79	44	48	59.5	63.5
July 1-7	83	89	44	55	63.5	72
" 8-14	83	87	46	55	64.5	71
" 15-21	84	88	45	56	64.5	72
" 22-28	81	94	43	65	62	79.5
" 29-Aug.4	81	88	44	59	67.5	73.5
Aug. 5-11	80	85	46	55	63	70
" 12-18	80	81	43	54	61.5	67.5
" 19-25	79	86	39	54	59	70

From the above table the following main points are apparent: (1) Higher maximum and minimum temperatures occurred during the 1931 season; (2) the maximum temperatures of the 1931 season were within the range causing rapid development of broods (above 85° F.), whereas at no time in 1930 did the average weekly maximum reach this range; (3) the minimum temperatures for 1930 at all times fell below the developmental point (55° F.), whereas in 1931 the minimum remained most of the time above the developmental point. These facts help to explain the completion of the life cycle during 1931 in such a short period and also the reason for greater rapidity of development than in the log at 75° F. constant.

This information will also throw some light on the number of generations produced in a single season at different altitudes where temperatures are different, and at the same altitude under different seasonal temperature conditions.

Study of Factors Limiting Successful Attacks on Standing Green Trees

The difficulty of establishing successful attacks on caged green trees in 1930 gave rise to further experimentation along this line in 1931. In 1930 very little difference in attack was found on trees of even the slowest growth rate compared with faster-growing trees. This fact led to the belief that growth rate was not as important as certain other factors, such as (1) feeding habits of the beetle prior to attack; (2) an upset in the physical condition of a tree, such as that caused by girdling; (3) the position of the cage on the trunk; and (4) disturbance of beetles due to handling. These four factors were studied in 1931 by the use of five cages.

1. S.v. feeding habits. Cage 4 completely enclosed a small white fir 4 inches in diameter by 14 feet high. In it were placed brood logs so that emerging beetles could begin work at once. This cage was used primarily for the purpose of determining whether the feeding habits of the adults included as part of their diet the foliage or small twigs of white fir before they could attack the main trunk. Since foliage was never included inside any cages in past experiments, this was a good opportunity to try out that test.

The cage was constructed and brood logs admitted on July 8. Heavy emergence had already taken place and attacks were started by July 21. Attacks continued heavy on the main trunk from this time on until the cage was removed and the tree felled for analysis on August 17.

The analysis showed that (1) 371 attacks were made along the main trunk, none of which was successful; (2) no feeding whatever occurred on the foliage or twigs: (3) all attacks were confined to the main trunk; the heaviest attacks occurred in the lower part, where the bark was thickest.

2. Effect of girdling trunk on attack. Cages 1 and 2 were constructed around two trees nearly identical in diameter, height and crown class, enclosing 20 feet of trunk from 6 to 26 feet above the ground. In each case a single width of screen was used, the seam being nailed tightly between two ½x3-inch strips. Bottom and top of each cage were drawn tightly against smoothed bark of the trunk by means of #9 telephone wire. Beetles were admitted by means of a hole cut in each cage. Caged tree 2 was girdled by removing a band of bark two feet wide below the cage, while Tree 1 was left intact. Beetles were introduced daily in Cage 1 from June 26 to July 7, when a total of 1270 S.v. were admitted. Between July 7 and 13, 1330 S.v. were admitted to Cage 2. Caged tree 1 was felled three weeks after the last beetles were admitted, and caged tree 2 was felled four weeks after the last beetles were admitted. In each case there was no further evidence of attack or presence of living adults in the cage when the trees were felled for analysis.

Table 3 - Analysis of Cages 1 and 2

Cage No.	Date Felled	No. of S.v. admitted	Total No. of Attacks	No. of attacks Reaching Cambium	Bark Area Caged	Longest egg gallery mm.
1	7/27	1,270	1,418	630	37.12	40
2	8/10	1,330	2,065	790	38.22	36

All attacks were unsuccessful; even the longest egg galleries were "pitched out" in both trees. Girdling had no effect on the success of attack and, if anything, made conditions more unfavorable to attack on account of increased moisture conditions under the bark. In each case more than twice the number of attacks were made on the outer bark as reached the cambium.

3. Effect of caging upper part of trunk on attack. Cage 5 enclosed 12 feet of the upper part of the trunk from 30 to 42 feet above the ground on a moderate-growing white fir. This part of the trunk, smooth bark and moderately thin, is attacked first in most instances when trees are killed. For this reason, beetles introduced into a cage built around the upper part of the trunk should find conditions more favorable to attack.

The cage was constructed July 9. Between July 14 and 22, 1045 beetles were introduced into the caged area enclosing 24.6 feet of bark surface. The tree was felled, cage removed, and the caged area analyzed on August 17, when there was no further evidence of attack.

Like all the other experiments, attacks were unsuccessful. A total of 188 attacks were made, three of which included egg galleries 44, 45 and 48 millimeters long respectively with eggs. The eggs had turned black and the galleries were filled with balsam.

4. Handling of beetles eliminated. Cage 3 was built around a moderate-growing tree on a southern exposure where conditions for attack were considered most favorable. Several trees in the immediate vicinity of the cage had been attacked during the previous season, and the possibility of successful attacks being established looked altogether favorable.

The cage was constructed so that logs containing brood could be admitted, thus allowing the emerging beetles to attack the tree directly without any handling. It enclosed the lower part of the trunk from 6 to 24 feet above the ground. Brood logs were introduced July 1 and emergence from them was first noted July 6. Periodic examinations were made a week apart until August 18, when S.v. adults were no longer seen within the cage. A thorough examination of the trunk inside the cage resulted in finding no successful attacks. As in all other caged trees many attacks were made, but conditions were not right to permit the beetles to become established.

5. Discussion of caging experiments and possible explanations for unsuccessful attack. In two seasons, wherein ten different trees were caged and beetles forced to attack them, not one of the trees contained a successful attack. Conditions were varied so that (1) growth rate of the trees was tested; (2) position of the cage on the trunk was tested; (3) feeding habits of the beetle were tested; (4) tree injury by girdling and the effect on beetle attack was tested; and (5) disturbing the beetles was eliminated. Since none of the above factors in any way improved conditions for success of attack, it is concluded that some factor within the tree not yet found is responsible for the failure.

Analyses made on all attacks have shown that balsam has been present, more in some cases than in others; whereas, compared to successful attacks on either trap logs or successfully-attacked standing trees, balsam is lacking in the entrance hole, nuptial chamber and egg gallery. This fact was noted early in the caging experiments and was one of the chief reasons for varying the position of the cage on the trunk, since it was thought that less balsam would be found in the upper portion. The change in position, however, has since shown that balsam is secreted to the same extent in attacks made in the upper part as lower down.

A striking discovery was made by Dr. Gordon late in the 1931 season, when he found that when a drop of balsam from one of the resin blisters of white fir is placed on an adult S.ventralis, it ceases movement within less than ten seconds and remains so until dead. A series of tests run by Gordon and Struble later showed that (1) when a drop of balsam is placed on the abdomen of a beetle it ceases movement within ten seconds; (2) when balsam is placed on the head, the beetle backs up for a period of several minutes; (3) when balsam is placed half an inch in front of an approaching beetle, it throws back the antennae and turns in the opposite direction; (4) when placed in a ring of balsam a beetle hesitated for 20 minutes, then walked forward until the head touched the balsam. This stimulated the beetle to walk backward until the other side of the ring was touched by the abdomen. Within a few minutes the beetle ceased movement and died.

These preliminary tests show with considerable certainty that (1) balsam is repellent, and (2) that it is either toxic or kills the beetle by closing the respiratory system.

Since balsam is so definitely repellent and toxic to the adults, it is certainly plausible that successful attacks on green trees are largely influenced by the absence or reduction in quantity of balsam. Analyses of caged trees have all shown that nearly twice as many attacks were made as reached the cambium. This may be explained by the fact that as a beetle bored through the outer surface of the bark and struck a balsam reservoir, it immediately backed out and tried somewhere else.

Continued studies on this phase of the fir engraver problem should be carried on to determine whether balsam is localized under certain conditions which may permit attack, and to determine whether this factor alone is responsible for attack.

The water content in a tree may also be an important factor. When a tree is felled and limbs are left on, transpiration continues and rapidly dries out the trunk. Under these conditions attacks of S. ventralis are started within one week after the tree is felled. When limbs are cut off, attacks are not established until well over a month and in some cases not at all. There is also a possibility that the balsam is localized more rapidly in trees felled and limbs left intact, due to transpiration. Further studies along these lines are necessary in order to determine the conditions favorable to successful establishment of S.v.

CONTROL STUDIES

Three methods were tried in the course of this study, as follows: (1) solar heat treatment; (2) chemicals used as insecticides and repellents; (3) submerging brood logs in water. Control by felling trees and burning broods was not considered, since fire conditions were too grave to warrant experimenting with this method.

Solar Heat Experiments

1. Determination of fatal temperatures. Preliminary experiments were run in the Berkeley Laboratory during the spring of 1931 to determine the temperatures fatal to broods. The technic employed in this study was similar to that used by J.M. Miller in determining the effect of warm air temperatures on D.brevicomis larvae.* Vials containing 20 larvae each were sealed with paraffined corks and partially submerged in water. The water was heated slowly through a range in temperature from 90 to 130° F., allowing 30 minutes between each 5° rise. Thermometers inserted through the cork of every other vial containing larvae made it possible to record the temperatures affecting the larvae. One vial was removed after each 5° rise, and a careful record of larval activity made. When the fatal range of temperatures was found, tests were run to determine the length of time required for mortality at a given constant temperature within the fatal range.

Three tests were run by gradually increasing the range of temperature from 90 to 120° F., and one with a gradual increase from 110 to 135° F. Constant high-temperature tests were run for maximum periods of 2½ hours at 115° F., 3 hours at 120° F., and 1 hour at 125° F. A total of 780 S.v. larvae were used.

From these experiments it was found that (1) the activity of larvae was accelerated between 95 and 100° F., but slowed down decidedly at 105° F.; (2) at temperatures of 110° F. and above activity ceased and temporary paralysis set in; (3) recovery from paralysis was rapid for most larvae at all temperatures between 110 and 120° F.; (4) death resulted from prolonged exposures to all temperatures above 120°F.

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*Miller, J.M. Some Temperature Points Affecting the Western Pine Beetle. Ms. July 1929; Stanford University, Calif.

Table 4. Effect of Gradual Temperature Increase on S.v. Larvae

Test No.	Temperature Degrees F.	Condition After Exposure	Cond. After 4 Days: Active	Dead	% Mortality
3	90--95	Normally active	16	4	20
	95-100	Activity greater	15	5	25
	100-105	Slight activity	18	2	10
	105-110	Inactive; slight activity when stimulated	18	2	10
	110-115	No activity; paralysis	16	4	20
	115-120	do	19	1 paralyzed	
4	110-115	Inactive--rigor	19	1	5
	115-120	do	18	2	10
	120-125	do	2	18	90
	125-130	do	All	dead	

Tests at constant high temperatures showed that (1) 2½ hours at 115° F. was insufficient to kill all the larvae (one adult survived this exposure); (2) one hour at 120° F. was sufficient to kill all the larvae; (3) one-fourth hour at 125° F. was sufficient exposure to kill the larvae.

The following table summarizes the results of this test:

Table 5 - Effect of High Constant Temperatures on Larval Mortality

Temp. °F.	Period hours	Per cent Living After: 4 days	10 days	Remarks
115	1	100	50	All dead after 30 days
	1½	100	60	Four adults after 30 days
	2½	90	75	One adult " 30 "
120	1	65	25	All dead after 15 days
	2	55	55	" " 20 "
	3	0	0	
125	¼	30	10	" " 15 "
	½	25	5	" " 15 "
	1	10	0	

2. Bark temperatures of logs exposed to the sun. Twelve-inch laboratory thermometers graduated in even degrees from 0 to 220° F. were inserted in the north ends of brood logs having different bark thicknesses. Holes slightly larger in diameter than the thermometers were bored with a brace and bit on a slant from the wood in the end of the log to the inner bark. One hole each was made for east, top and west exposures of the log to the sun. As thermometers were inserted, cotton plugs were forced in tightly around them to prevent any circulation of air about that part of the thermometer in the log. The exposed part of each thermometer was enclosed in a white paper cylinder, where it was protected from the rays of the sun. Readings were recorded every two

hours during the day, and in addition the air temperature was taken from a thermometer hung in the shade. Three tests were run during the summer season in brood logs which varied in bark thickness from 5 to 16 millimeters. All logs were placed so that full sunlight could strike them between 9 a.m. and 5 p.m.

These tests showed that (1) lethal temperatures were reached in bark 4 mm., 10 mm., and 16 mm. thick when the air temperature was 70, 75 and 82° F. respectively. In other words, 82° F. air temperature was required for lethal temperatures to be reached in the 16 mm. bark; (2) lethal temperatures were reached on top and west, but not on the east side of all logs; (3) bark temperatures reached 140° F. in bark 10 mm. thick when the air temperature was 92° F.

The following table gives a summary of air temperatures and bark temperatures at the same time in different thicknesses of bark and at different exposure to the sun:

Table 6 - Comparison of Air Temperatures to Bark Temperatures

Time of Day	Air Temp. ° F.	Bark Temperatures							
		Log #1 Bark 16 mm. Thick			Log #2 Bark 10 mm. Thick			Log #3 Bark 4 mm. Thick	
		East	Top	West	East	Top	West		
10:00 a.m.	70	108	97	81	111	115	74	129	
12:15 p.m.	75	103	115	83	95	128	100	126	
1:30 p.m.	82	98	121	100	96	128	101	117	
4:15 p.m.	88	92	110	125	93	112	138	110	

The daily fluctuation of air temperatures compared with bark temperatures is shown in Chart II, when two logs of average bark thickness were used. Fatal temperatures were reached on the top and west exposures, but not on the east. At an air temperature of 75° F., lethal temperatures (above 120° F.) occurred in bark 10 mm. thick. At air temperatures above 80° F. lethal temperatures occurred in the tops of all logs.

3. Effect of solar heat on brood mortality. The first test was run from June 18 to July 7, during which time air temperatures varied between 63 and 88° F. Logs were rolled over on June 30, a few days after lethal temperatures had been reached. Between June 30 and July 7 lethal temperatures occurred. On July 7 all logs were carefully examined and the bark was worked up to detect any living brood. The examination resulted as follows: (1) In Log 1, bark 16 mm. thick, and Log 3, bark 4 mm. thick, all broods dead. (2) In Log 2, bark 10 mm. thick, 22 living S.v. larvae found on the west side; remainder of broods dead. All these were near a thickened part of bark surrounding a branch which had been lopped off.

The second test was run between July 8 and July 29, when air temperatures varied between 75 and 93° F. On July 13 a portion of the bark from each log was removed and counts were made on broods to determine amount of kill. These counts showed that all S.v. broods were killed on the top exposure of two of the logs and that only 4 S.v. individuals were living in the third log; (2) that all associated insects were killed on Logs 1 and 3, and all except 3 Temnochila virescens larvae and one flathead larva on Log 2. The following table summarizes these counts:

Table 7 - Brood Mortality in Tops of 3 Logs Exposed to Sun July 8-12

Log No.	Bark Area Sq. Ft.	Living Broods: S. ventralis L.	S. ventralis P.	S. ventralis N.A.	T.v.c. L.	Cl. L	Dead Broods: S. ventralis L.	S. ventralis P.	S. ventralis A.	T.v.c. L.	C. L.
1	2.52						11	25	38	10	
2	2						61	30	47	8	3
3	1.4		1	3			13	27	27	1	

All logs were rolled over and thermometers reinserted on July 15. Log 3 was placed in the shade on July 18, 3 days after exposure, while Logs 1 and 2 were left in the sun until July 19, 4 days after exposure. Counts were made on 1 sq.ft. of bark from each log. Each section was divided into 3 parts, east, top and west, covering the top half of the log, to determine whether there was any difference in brood mortality. The count revealed that all broods, S.ventralis and associated insects were killed. The following table gives the total S.v. brood and predators killed for each sq.ft. of bark sampled:

Table 8 - Mortality of Broods in 1-Foot Sections

Log No.	Bark Area Sq.Ft.	Bark Thickness mm.	Days Exposed to Sun	S. ventralis L.	S. ventralis P.	S. ventralis N.A.	Osto-mids	Clerids
1	1	15	4	1	38	109	1	1
2	1	12	4	9	13	60	1	0
3	1	10	3	26	3	0	0	2

The third test was run between Aug. 7 and Aug. 17, when air temperatures ran between 75 and 87° F., on logs having bark thicknesses of 12, 17 and 5 mm. Strips of bark were removed from the top surfaces of the logs on Aug. 11 and the logs were then rolled so that the bottom surface was up. Counts to determine the amount of brood mortality in the removed strips resulted as follows: (1) All broods except 1 S.v. larva in Log 2 and 8 S.v. larvae in Log 3 were killed. These were found in an area protected by a knot; (2) the dead broods consisted of 571 S.v. larvae, 18 S.v. pupae, 13 S.v. adults, 19 clerid larvae and 5 ostomid larvae; (3) the bark area containing these broods amounted to 4 sq.ft.

All logs were removed from exposure to the sun on Aug. 17 and counts were made as before on living and dead broods. These counts indicated complete mortality of all broods in Logs 2 and 3, but in Log 1 27 living S.v. larvae, 1 clerid larva and 4 ostomid larvae were found on the east side. All broods were dead on top and west side of the same log.

4. Conclusions and Recommendations. The difficulty of inserting thermometer bulbs into the bark so that an accurate record of temperature found therein could be secured, has given rise to possible error in this study. These discrepancies were in a measure taken care of, however, by the number of tests run during the experiment, and reasonable assurance for correctness of recommendations on the basis of the above sun-curing tests is given.

The following recommendations are made for the solar heat method of control for the fir engraver beetle: (1) Application of the method is feasible only when air temperatures in the shade are above 80° F. Thorough killing of broods can be secured on the top surfaces of logs of medium thickness up to 20 mm. Since the broods are always heaviest in bark from 4 to 16 mm. thick, this method is good when temperatures are high enough. Broods under thick bark must be treated by some other method.

(2) Logs to be treated should be felled in a north and south direction in open sunlight, where the full force of the sun's rays can be effective for at least six hours during the middle of the day.

(3) Logs should be rolled three times; i.e., one-third of the circumference is all the area that can be effectively treated at one time. Four-day intervals between each rolling should elapse to make sure of an effective kill. A record of air temperature should be kept as a guide to the effectiveness of suncuring.

(4) If logs have considerable brood in bark too thick to be suncured, the thick bark should be removed and laid flat in the sun with the inner surface up. Suncuring from the inside may be more effective.

Chemical Control Experiments

Flu-si Dust

This chemical, manufactured by the Michel & Pelton Co., Oakland, Calif., consists of ingredients as follows: active, sodium fluosilicate, 70%; balance, inert material, 30%. It is advertised to be "twenty times more poisonous against most insects than arsenic," and "one hundred times less poisonous to humans and animals than arsenic." It is applied by dusting, either with a hand duster or dusting machine, and will kill "both by contact and as a stomach killer; when insects crawl through it they burn themselves, and in cleaning themselves introduce it into their stomachs. It kills in from three to five days, and will remain active for many days."

Preliminary tests were run in Berkeley in the spring to determine the effectiveness of Flu-si dust on the fir engraver beetle. These tests were tried (1) to determine the rate of mortality of beetles placed in a petri dish after they had been allowed to crawl over dusted paper, compared to an equal number of undusted beetles in another petri dish; (2) to determine whether dusted logs were rendered more attractive to beetles and whether such dusted logs could be successfully attacked.

1. Effect on beetles. Experiment 1: to determine whether S.V. adults would be killed by walking over Flu-si dust. Two tests were run as follows: (1) a thin film of Flu-si dust was spread over a sheet of paper; (2) twenty S.V. adults were allowed to walk, one at a time, over the paper; (3) all beetles were collected in a petri dish with a layer of filter paper on the bottom; (4) two drops of water were put on the filter paper to keep the air moist inside the dish. Checks were run by placing the same number of untreated beetles in another petri dish. The following table gives the results of these tests:

Table 9--Mortality of Beetles Subjected to Flu-si Dust Compared with Checks

	Flu-si Dust				Check		
Hours After Exposure	Number Living	Dead Adults	Per Cent Mortality		Living Adults	Dead Adults	Per Cent Mortality
			Test 1				
24	20	0	0		20	0	0
40	17	3	15		20	0	0
88	18	18	90		8	12	60
136	0	20	100		5	15	75
			Test 2				
42	12	8	40		19	1	5
68	8	12	60		19	1	5
116	1	19	95		8	12	60

Although considerable mortality occurred in the checks used in the above tests the effectiveness of the chemical is fairly positive after the extended period.

2. Influence and effect of Flu-si on attack. Experiment 2: two longs, both with smooth bark, were used. One was dusted, the other left as a check. Both were placed in a cage where S.V. adults were admitted, and in such a position that illumination was equal. The S.V. adults were placed on a sheet of paper midway between the logs. Eighty adults were admitted at the beginning of the experiment on March 25.

The results of this test indicated that (1) there was no preference shown for the non-dusted log over the dusted log. In other words, Flu-si did not act as a repellent. (2) Attacks were made on both logs, but in neither of these were eggs laid by April 16, when the experiment was closed. (3) Heavy mortality occurred around both logs, indicating that Flu-si had an irritant effect on the beetles and caused them to crawl from one log to the other. (4) One living beetle was found on each log on April 16; both were actively working under the bark of each log. (5) Further tests were necessary to eliminate the possibility of beetles on the check log being contaminated with Flu-si.

Experiment 3. In this experiment check logs and Flu-si-dusted logs were placed in separate cages with emerging beetles. Cage 1 contained check logs 1 and 2, while Cage 2 contained logs 3 and 4, treated with Flu-si. Logs 1 and 3 were similar, each having thin smooth bark, and logs 2 and 4 were alike, having rough bark somewhat thicker than logs 1 and 3.

All logs were placed in their respective cages with brood bark on May 8. Emergence started on May 16, and by May 19 attacks were being made. Periodic examinations showed that attacks were made on all logs, that check logs were attacked more profusely than treated logs, and that the smooth logs, treated and untreated, were attacked more heavily than the rough-bark logs. None of the logs was disturbed, however, until June 29, when the bark was removed from all of them and counts were made on the number of attacks.

This analysis showed (1) that 95 attacks were made on the smooth untreated log compared with 16 attacks on the smooth dusted log; (2) that 64 attacks were made on the rough untreated log and 28 attacks on the rough dusted log; (3) that 24 of the attacks on the smooth untreated log contained eggs and small larvae, whereas only 2 attacks on the treated smooth-bark log were found which contained eggs and small larvae.

Table 10, which follows, gives a comparison of the success of attacks in this experiment.

Table 10 - Comparison of Attacks on Dusted and Undusted Logs

Log No.	Description	No. of Attacks	No. of S.V. Present	No. of S.V. Dead	No. of Attacks with Eggs and Larvae	Longest egg gallery, mm.
1	Smooth Check	95	25	24	24	90
3	Smooth Dusted	16	8	6	2	102
2	Rough Check	64	15	12	5	90
4	Rough Dusted	28	4	4	0	32

The results of this experiment show (1) that Flu-si dust has a definite influence on the number of attacks, due to the poisonous effect on the beetles; (2) that some beetles are able to resist the poisonous effect of Flu-si, and as soon as they bore beneath the surface of the bark can extend egg galleries and lay eggs.

Creosote Emulsion of Arthur Cenn

The constituents and proportions of this emulsion are not definitely known, since its inventor refused to give any information concerning it. The strong odor of creosote, however, unquestionably established it as an emulsion of this compound. Recommendations for a 4 per cent emulsion with water were given for its use without harm to plant tissue.

Certain preliminary tests were carried out in which the emulsion was used, (1) to determine whether sprayed logs would be attacked; (2) to determine the effect on attacking beetles; (3) to determine whether broods would be killed by creosote emulsion sprayed on the bark; and (4) to determine the effect of the emulsion on plant tissue.

1. Study of effect as repellent. Experiment 1. A smooth-bark green log 4 feet long was thoroughly sprayed with a 4 per cent emulsion of creosote and water on July 8. Another similar log was left untreated as a check. Both lay on the ground as trap logs for beetles in flight. No attacks were found on either log by July 23. On July 23 four attacks were found on the check and none on the sprayed log. On August 4 both logs were analyzed, when it was found that the treated log had 2 S.v. attacks and the check log had 7 S.v. attacks.

Experiment 2. Two green logs were placed in a cage July 23. One was thoroughly sprayed with a 4 per cent creosote emulsion and water and the other was left untreated. S.ventralis adults were then admitted from rearing cages. A total of 210 of them was admitted by July 26. On August 3 the logs were taken out of the cages, bark was removed, and analyses were made on the number of attacks. The results of this test showed that 55 attacks were made on the treated log and 19 attacks on the check log.

2. Effect on attacking beetles. This experiment was conducted in the laboratory at Berkeley. A green untreated log was placed in a cage with emerging beetles on March 23. Three days later a heavy attack had been made. The log was removed from the cage and sprayed with a 4 per cent emulsion. This caused sudden stimulation of all beetles, wherein they backed to the surface of the bark and were shortly paralyzed by the effect of the emulsion. By March 31 all beetles within the log and those that backed out were dead.

3. Effect of emulsion on broods beneath bark. A log 2 feet long with thin bark containing a brood of S.v. larvae about 3 weeks old was thoroughly sprayed with a 4 per cent emulsion on July 23. Two examinations made, one July 28 and another August 3, revealed positively no effect on the broods beneath the bark.

4. Effect of emulsion on living plant tissue. In this experiment two young white fir trees were sprayed with a heavy application of 4 per cent emulsion on July 13, so that all surfaces, trunk, limbs and foliage were covered. Periodic examinations were made until September 1, but no detrimental effects could be observed on either tree.

5. Discussion of results. In the preceding experiments the results have been such that little hope can be expected for the use of creosote emulsion as an effective treatment against the fir engraver beetle. The two experiments testing the repellent qualities showed that the insects were not affected to any appreciable extent by the emulsion; in fact,.in the second experiment it would appear that they were even attracted by it.

Beetles beginning a new attack may be drawn out of their entrance holes by the strong irritating effect of the emulsion when it is applied; but soon after it dries the toxic qualities are evidently lost, and new beetles may resume an attack.

No effect whatever on broods beneath the bark is caused when the emulsion is applied to the outer surface of the bark.

Solite

This substance is an oil spray put out by the Stewart Oil Products Company of San Francisco. It consists of 92 per cent petroleum oils and 8 per cent inert ingredients. Samples of this oil were donated for experimental use against the fir engraver beetle. One experiment was run to test the repellent effect of a green log sprayed with the recommended dilution of 1-100. The log was sprayed on March 20. By March 23 many S.v. attacks were found on the log, indicating no repellent action. No further tests were run with this oil.

Paradichlorobenzene in Linseed Oil

A solution of one ounce paradichlorobenzene in 2 ounces of linseed oil as a possible means of control for the fir engraver beetle was suggested by F.B. Herbert of Balfour, Guthrie & Co., Ltd., San Francisco. The use of this material was still a matter of experiment at the time it was suggested, and therefore no prediction of what results could be expected were given.

In theory, the mixture applied to the outer surface of infested bark would, due to the penetrating qualities of linseed oil, reach the broods beneath, where paradichlorobenzene dissolved in the oil would kill them. Both repellent and penetrative qualities were tested during the course of experiments with this mixture.

1. Test of penetration. Experiment 1. A log with thin bark and 2 feet long, which had a three-weeks-old S.ventralis brood, was painted with a heavy coat of linseed oil solution of paradichlorobenzene, 2-1, on July 25. On August 3 the bark was removed, exposing the brood. The examination showed that (1) there was no visible penetration of the oil into the bark, and (2) no mortality of brood resulted from the treatment.

Experiment 2. Two green smooth-bark white fir logs, each 4 feet long, were stood on end where beetles in flight could attack them. On July 8 one was painted and the other was left intact. Neither log was attacked by July 23, but by August 4 an analysis showed that on the check log there were 1 S.v. and 2 S.praeceps attacks, and on the treated log there were 4 S.praeceps attacks. All the S.p. attacks were made directly through the heavy film of oil on the outer surface. Only a trace of the odor of paradichlorobenzene could be detected at the time of this examination.

2. Effect as a repellent. Experiment 3. Two green smooth-bark white fir logs were placed in a cage. One was painted with a heavy coat of linseed oil and paradichlorobenzene, 2-1, and the other was left unpainted. S.ventralis adults were admitted to the cage from rearing cages between July 24 and 26 until there was a total of 240 beetles. Both logs were examined on August 3 with results as follows: (1) Attacks on treated log--14; (2) attacks on check log--67. It was noted that all attacks made on the treated log were in protected situations, such as beneath raised bark and near limb butts, where there was not a thorough covering of oil.

3. Effect on living plant tissue. No detrimental effect of the solution painted on a young thin-bark white fir on July 25 was observed by September 1.

Thymol

The use of this chemical as a repellent was tried in an experiment in conjunction with others already mentioned on a trap log, as follows: Four feet of the upper part of a tree felled for a trap log was painted with a saturated solution of thymol in alcohol on July 31. An equal length of trunk was left untreated as a check. An analysis made on August 25 gave the following results: Treated portion--two attacks with egg galleries and eggs; untreated--no attacks. A strong odor of thymol was present on the date of analysis.

Discussion and Conclusions

The application of chemicals as insecticides or repellents against the fir engraver beetle appears at the present time to be of little value. A certain measure of protection may be afforded by the use of Flu-si dust, but it is by no means an absolute guarantee against attack. Many of the beetles are apparently able to resist the toxic effect of this preparation and continue their attack. Application of the paradichlorobenzene in linseed oil solution also repelled attack to a limited extent, but not enough to be of much value. In no instance were any of the chemicals strong enough to penetrate through the bark and reach the broods beneath it. The feasibility of continuing studies by use of the above chemicals through applying them externally does not seem justifiable because (1) the toxic or repellent qualities do not last long enough, and (2) the mechanical composition of fir bark does not permit penetration to an appreciable depth.

Submerging Logs in Water

Eight logs, each 1 foot long, containing heavy broods of S. ventralis, were completely submerged in water by weighting them with rocks in the Stanislaus River. This experiment was begun on July 7. Two logs were removed after the first week, and each week thereafter one log was removed. All logs were allowed to dry out for another week, when the bark was removed and counts were made to determine the amount of brood mortality. A record of bark thickness was kept to determine whether brood under thin bark was killed more quickly than that under thick bark.

A surprising amount of resistance was found in broods exposed to this treatment. Seven of the logs were removed from the water during a six-week period. Careful analyses were made by removing the bark and shaving it up to expose all the brood. Some difficulty was experienced in determining whether or not a larva or pupa was actually dead. These doubtful cases were kept separate, but in figuring the table showing percentage brood mortality the doubtfuls were figured as living. The following table summarizes the results of this experiment:

Table 11 - Submergence Test Showing Percentage Brood Mortality of S.v.

Log No.	Submergence Time in Weeks	Bark Area Sampled Sq.Ft.	Bark Thickness mm.	Percentage Mortality S.ventralis
1	1	2	18	14
2	1	1	12	20
3	2	2	13	38
4	3	3.1	15	53
5	4	3.2	14	78
6	5	2.8	15	80
7	6	2.8	12	99

In this test a constant increase in kill is evident as the period of submergence is lengthened. Bark thickness is evidently not a very important factor in the submergence method of control after a certain period, when bark on all the logs becomes saturated to its fullest extent. Saturation, however, must be reached very slowly in certain parts of the bark. This factor, correlated with greater resistance of some of the brood, may explain why it takes longer to kill some individuals than others.

As a practical method of control, submerging logs in water is feasible only when a body of water is near at hand. Heavy infestations of the fir engraver beetle near lake shores may be controlled in this way. Brood logs dropped into mill ponds should be left there for a period of six or eight weeks if broods are to be killed. The method at best is very slow and cannot be recommended with a great deal of enthusiasm.

COMPARISON OF INSECT LOSSES (1930 AND 1931) ON C.F.E.S. PLOTS AND BUREAU OF ENTOMOLOGY PLOTS

Surveys were made on these plots during the month of August, when a complete record of all 1930 losses and a partial record of 1931 losses could be secured. Nine plots are included, seven of which are used by the California Forest Experiment Station to study silvicultural problems and two by the Bureau of Entomology for further investigation of insect conditions.

The individual losses for each plot are shown in the table which follows. The 1930 loss figures are complete; i.e., they include figures taken as a result of surveys during both seasons, 1930 and 1931, when in the latter survey all 1930 trees could be spotted. The 1931 loss figures in the table cannot be considered complete because of the difficulty in locating infested trees which had not begun to fade at the time of the survey. Though a resurvey in the summer of 1932 will complete the 1931 loss, the probability of finding enough white fir trees to equal the 1930 loss on any of the plots is small. Yellow pine and sugar pine have shown a decided increase in 1931 on some of the plots where these two species are prevalent.

The decline of infestation due to attacks of the fir engraver in 1931 is contrary to the behavior of other bark beetles during a drought period. The effect of the dry 1930-31 year upon sugar pine and especially on yellow pine was very evident in reducing the vitality of these two species to the point where D.monticolae and D.brevicomis were able to kill large numbers of trees. Quite the contrary was the case with white fir, which showed exceptional resistance to fir engraver attacks. This condition was confined not only to the Stanislaus region, but also to all areas in the Sierra fir belt which had suffered heavy losses during 1928, 1929 and 1930. Observations during the 1931 summer season in the Northern Sierra region on the Modoc, Lassen and Plumas National Forests, by J.M. Miller and K.A. Salman, and in the Tahoe region of the Tahoe National Forest by the writer, indicated a definite decline in the number of fading and red-top white and red fir.

The reasons for the decline during one of the driest years of the drought period (1924-1931) cannot be definitely explained, except by a possible increased resistance of fir to insect attack by a greater production of balsam, or to a decrease in virulence of the fir engraver by disease or increased parasitism. The failure of successful attacks on green white fir trees of very slow growth rate--a result of 1930 experimentation--indicates a resistance independent of growth rate induced by drought periods.

Table 12 - Insect Losses for 1930 and 1931 on C.F.E.S. and B.E. Plots

Plot No.	Area Acres	Plot Description	Spec	1930 Insect-Killed Poles	1930 Insect-Killed Merchantable Timber: Trees	1930 Insect-Killed Merchantable Timber: Volume Bd.Ft.	1931 Insect-Killed Poles	1931 Insect-Killed Merchantable Timber: Trees	1931 Insect-Killed Merchantable Timber: Volume Bd.Ft.	1931 Topkills Trees
M.E.--1	5	Pure W.F.;virgin	WF	0	0	0	0	0	0	0
M.C.--5	10	Heavy cut, 1923	WF	3	3	360	0	1	210	1
		Slash disposal	WF	1	5	1,230	0	2	200	0
" 7	160	cut, 1923	SP	0	0	0	0	2	1,160	0
		SP Reproduction								
" 8	8.4	Study Cut 1928	WF	2	2	500	0	0	0	0
		F.S.Cutting Meth-								
" 9	15	ods:Cut 1929	WF	0	4	1,150	0	0	0	0
		Mason Cutting	WF	0	4	9,270	0	2	4,790	2
" 10	15	System;Cut 1929	SP	0	0	0	0	1	110	0
		Priv.Lands Cut.								
" 11	15	System:Cut 1929	WF	3	4	7,410	0	0	0	1
B.E. 1		Virgin WF and SP	WF	0	17	20,160	0	3	1,330	2
	40	S.Fk.Stanisl. R.	SP	1	2	400	1	2	19,010	0
		Cold Springs Cut-	WF	0	8	9,230	0	3	1,130	2
" 2	100	ting; YP, SP,	SP	0	0	0	0	4	3,470	0
		WF Type	YP	0	2	1,980	0	32	8,250	3

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Photo 1 (8400a). Insect rearing cage, dimensions 4'x4'x4' high, constructed of plaster board. It will easily accommodate from 10 to 14 brood logs of medium size. Mason fruit jars screwed into their caps, nailed along the upper edge of one side of the cage where holes have been bored, serve effectively in collecting emerging beetles. Three cages of this type were used in 1951 studies.

(Original)

Photo 2 (8400f). Cage 3, 4'x4' x18' high, with base 6 ft.above surface of ground. Brood logs placed within the cage enabled the emerging beetles to attack the trunk inside the cage directly, without disturbance. This tree, like all the others, resisted the attacks of the beetle.

(Original)

Photo 3 (8400b). Cage 4 completely enclosing a small white fir 4 inches in diameter and 14 feet high. Brood logs were placed within the cage where emerging beetles could attack the tree directly. Beetles began to emerge and attack by July 15, and on August 17 the cage was removed after all emergence ceased. Examination of the tree revealed 371 attacks, all unsuccessful, along the main trunk. No feeding by the adults occurred on twigs or foliage.

(Original)

Photo 4 (8400c). Cage 5 of the screen cylinder type, enclosing the upper part of the trunk from 30 to 42 feet above ground (arrows indicate cage). This part of the trunk is usually attacked first when trees are attacked in the field. 1,045 S.V. adults were admitted between July 14 and 22, but by August 17 no attacks were successful out of 188.

(Original)

SEASONAL DEVELOPMENT OF *SCOLYTUS VENTRALIS* LEC. BROODS REPRESENTED BY EGG GALLERIES AND LARVAL MINES ON SURFACE OF SAPWOOD

This series is composed of separate galleries exposed by removing bark at definite intervals after parent beetles entered bark. Each photograph represents a separate egg gallery resulting from attacks which occurred on a trap log at Pine Crest, California, July 5 to July 9, 1931. These were uncovered one week apart from July 9 to Aug. 13. Illustrations two-thirds natural size.

The development period from eggs to mature larvae was 42 days in 1931, due to unusually warm seasonal temperatures. Pupation and emergence then occurred before fall. From 75 to 90 days is the usual time required for larvae to mature in the fir belt, and cold temperatures at the end of this time cause the larvae to overwinter.

FIG. 1 — *Attack from 4 to 6 days old. Entrance and nuptial chamber at left and egg gallery with egg niches extended to right. One male and one female per attack; male remains near entrance while the female constructs the egg gallery. (Adult beetles were lost when bark was removed.)*

FIG. 2 — *Egg gallery about 10 days after attack. In this attack gallery was first constructed to left then to right of nuptial chamber. No choice is apparent in direction of gallery other than horizontal. Beginning of fungus stain development shown as darkened areas on each side of egg gallery.*

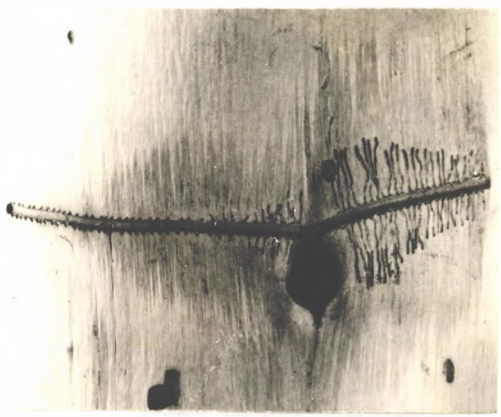

FIG. 3 — *Twenty days after attack; showing incubation of eggs and beginning of larval mines. Oldest part of egg gallery shown by longest larval mines and widest stain.*

FIG. 4 — *Thirty days after attack. Nearly all eggs have incubated except those last deposited near extreme ends of egg gallery. (Clouded area in upper part of photo due to bruising of sapwood in removing bark.) Arrow points to young larval mine of Sierra Fir Borer which followed the Fir Engraver beetle in attack on log.*

FIG. 5 — *Forty days after attack; with oldest larvae one-half to two-thirds grown. A few larval mines of the Sierra Fir Borer mixed with Fir Engraver beetle larval mines. Egg laying complete.*

FIG. 6 — *Forty-seven days after attack. Oldest larvae mature; some having already constructed pupal cells (see arrows). (Circular black area below entrance is small pin-knot; a similar knot is shown in FIG. 3.)*

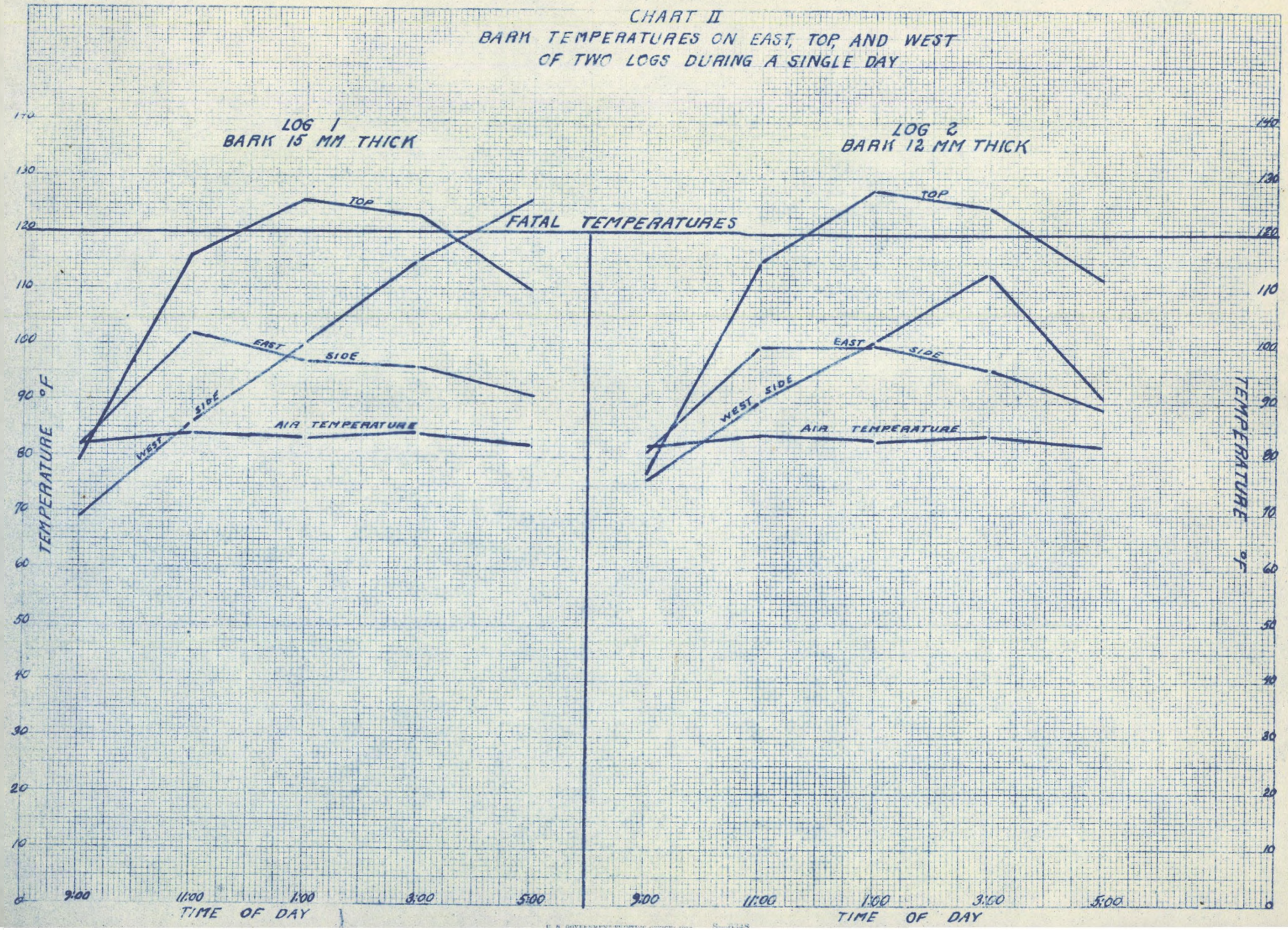
CHART II
BARK TEMPERATURES ON EAST, TOP AND WEST
OF TWO LOGS DURING A SINGLE DAY
LOG 1
BARK 15 MM THICK
LOG 2
BARK 12 MM THICK
TOP
FATAL TEMPERATURES
EAST SIDE
WEST SIDE
AIR TEMPERATURE
TEMPERATURE °F
TIME OF DAY
9:00
11:00
1:00
3:00
5:00
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0

CHART I

COMPARISON OF S. VENTRALIS BROOD DEVELOPMENT IN TRAP LOGS DURING 1930 AND 1931 SUMMER SEASONS IN RELATION TO TEMPERATURE

1930

1931

ATTACKS AND EGGS

LARVAE

LARVAE

1930-1931 OVERWINTER

PUPAE

NEW ADULTS

ATTACKS AND EGGS

FIRST GENERATION 1931

LARVAE

PUPAE

NEW ADULTS

ATTACKS AND EGGS

BEGINNING OF 2nd GENERATION 1931

NO DEVELOPMENT

MAXIMUM RANGE

OPTIMUM RANGE

MINIMUM RANGE

NO DEVELOPMENT

UPPER LIMIT OF DEVELOPMENT

LOWER LIMIT OF DEVELOPMENT

Daily Maximum Temperature

Daily Minimum Temperature

DEGREES F.

100 90 80 70 60 50 40 30 20 10 0

22 24 26 28 30 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

JUNE JULY AUGUST

1930

1931